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A QUANTITATIVE MINERALOGICAL CLASSIFICATION OF IGNEOUS ROCKS—REVISED

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PART I

In response to a request published in a former paper on a quantitative mineralogical classification of igneous rocks,[1] numerous letters have been received from petrographers in this country and abroad. Practically no objections were raised except against the separation of the feldspar molecules. With this separation the writer himself was not fully satisfied, and he reverted, shortly after the paper was published, to the subdivisions used by him when the classification was first presented to his students some nine years ago, namely, that of dividing the feldspars simply into plagioclase, on the one hand, and the remaining feldspars, on the other. In the following article this change is shown. A further modification is introduced in Class 4, although no objection was made to it as previously given. The new subdivisions are somewhat simpler than before.

An extensive change, embracing the omission of the 72 families of the monzonite series (Fig. 1), was contemplated, and personal letters were sent to a considerable number of petrographers asking opinions. Unfortunately the answers were so far apart that it has seemed best to allow the divisions to remain as they were. The need of more uniformity in classification was brought out clearly by the replies to this one question, as a comparison of the granite quartz-diorite series of several petrographers will show (Fig. 2).

Essentially the system now is as follows. For a detailed description the reader is referred to the former paper.

Classes.—On the basis of the amount of dark minerals (mafites) present, the igneous rocks are divided into four classes, the division points being 0–5–50–95–100 per cent mafites.

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[1] Albert Johannsen, "Suggestions for a Quantitative Mineralogical Classification of Igneous Rocks," *Jour. Geol.*, XXV (1917), 63–97. In that paper delete *eudialyte*, p. 90, l. 15, and change *less* to *more* under Class 1, p. 91, l. 26.

Orders.—Each of the first three classes is divided into orders (Fig. 3) according to the Ab–An ratio in the plagioclase. The division points are $Ab_{100}Ab_0$, $Ab_{95}An_5$, $Ab_{50}An_{50}$, $Ab_5\,An_{95}$, Ab_0An_{100}. There are thus formed, for each class, four double triangles (Fig. 4), in each of which three angles represent (1) quartz (Qu), (2) all feldspars except plagioclase (Kf), and (3) the feldspathoids (Foids).

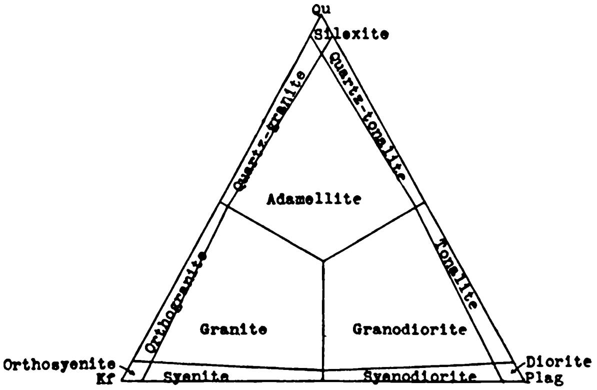

FIG. 1.—A proposed change in family divisions

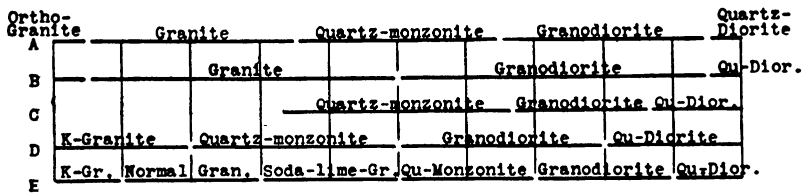

FIG. 2.—Variations in the usage of names in the granite quartz-diorite series: *A*, divisions used in the present classification; *B*, divisions suggested (cf. Fig. 1); *C*, Lindgren's original divisions; *D* and *E*, divisions as used by certain other petrographers. The right ordinate is orthoclase, the left, plagioclase.

The remaining angle (Plag) represents albite (Naf), oligoclase to andesine (Ca*Naf*), labradorite to bytownite (Na*Caf*), or anorthite (Caf), and these constitute the basis for the separation into Orders 1, 2, 3, and 4.

In Class 4, owing to the absence of light constituents, it is necessary to make the subdivisions on a different basis. In this class, therefore, each order represents an increased amount of the "ores" (Fig. 5). The division points, as in the other case, are 0–5–50–95–100.

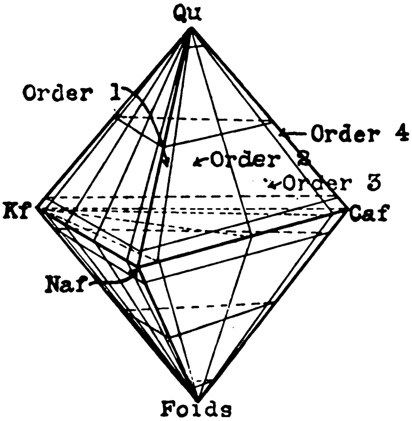

FIG. 3.—Subdivisions of the tetrahedron into orders.

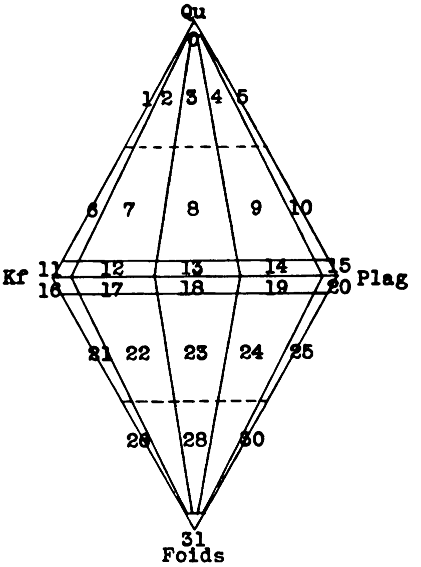

FIG. 4.—Family divisions in Classes 1 to 3.

Families.—Finally, each order is subdivided into families. In Classes 1, 2, and 3, the divisions, as shown in Figure 4, are at 0–5–35–65–95–100 on the feldspar base line, and at 0–5–50–95–100 from this line up or down toward quartz or the feldspathoids. Families 0, 1, 6, 11, 16, 21, 26, and 31 occur only once in each class (cf. Fig. 3), since the amount of plagioclase in each, whether it be albite, acid plagioclase, basic plagioclase, or anorthite, is too small to make an essential difference in the rock. These "hinge families" are classed, for convenience, in Order 1.

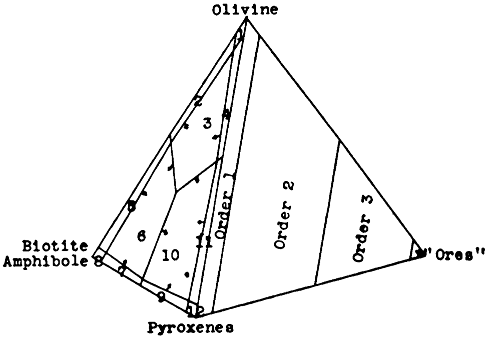

FIG. 5.—Orders and families in Class 4

In Class 4 the orders are subdivided as in Figure 5. The families are numbered from 1 to 12, as shown, and are divided at 0–5–50–

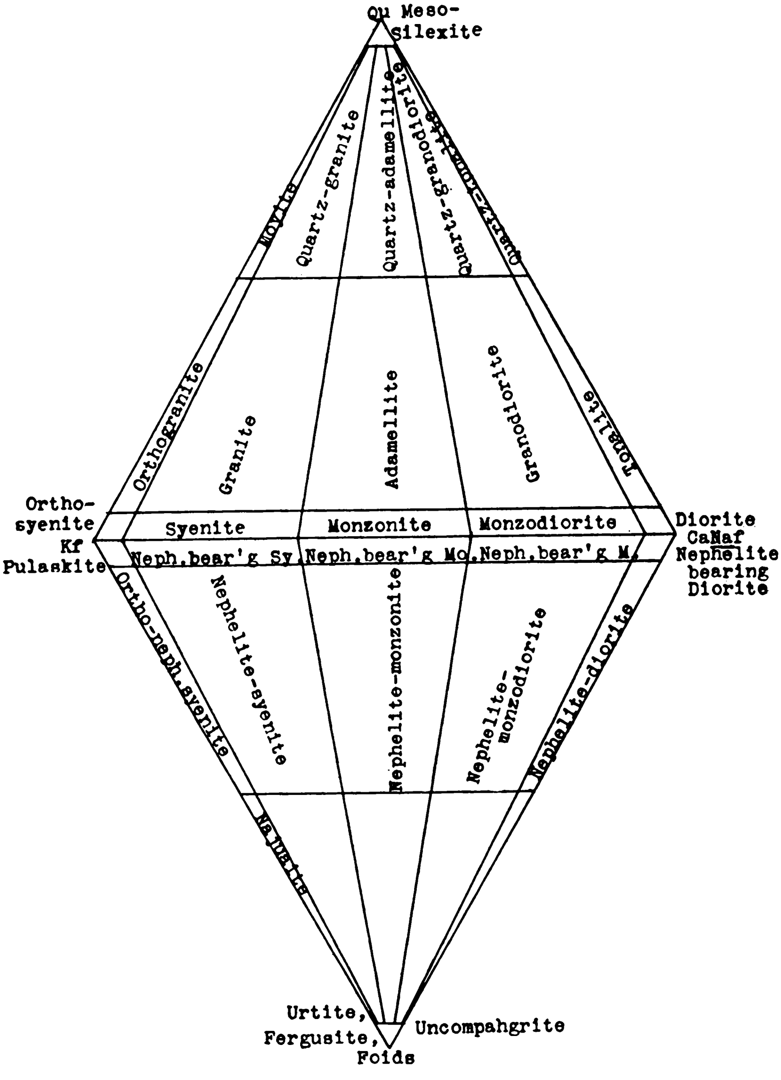

FIG. 6.—Families in Class 2, Order 2

95–100. The three corners, in Orders 1, 2, and 3, represent respectively olivine, biotite and (or) amphibole, and the pyroxenes. In Order 4, if thought desirable, the corners may be taken to represent the various ores; the writer, however, groups the ores in one family, for, considered as rocks, they are unimportant and hardly worth separating.

THE MINERAL GROUPS

The constituents of the rock are divided into three primary groups:

QUARFELOIDS

(Qu)	Quartz
(Kf)	Orthoclase, microcline, microperthite, anorthoclase, etc.
(Plag)	The whole isomorphous Ab–An series of plagioclases
(Foids)	The feldspathoids (nephelite, leucite, sodalite, hauynite, noselite, melilite, primary analcite, etc.)

MAFITES

Dark micas (biotite, phlogopite, etc.)
Amphiboles
Pyroxenes (including uralitized pyroxene)
Olivine
Iron "ores" (magnetite, ilmenite, chromite, pyrite, hematite, etc.)
Cassiterite
Minor Mafites
- Garnet
- Primary epidote
- Allanite, zircon, rutile, primary titanite, spinel, and other dark minor constituents

AUXILIARY CONSTITUENTS

The auxiliary constituents are seldom of importance.

Topaz
Tourmaline
Cordierite
Corundum
Fluorite
Andalusite
Primary scapolite
Primary calcite
Muscovite
Lepidolite
Zinnwaldite
Apatite, etc.

Most of the auxiliary constituents are light in color; they are, consequently, computed among the leucocrates.

SECONDARY CONSTITUENTS

Secondary constituents are to be calculated as the originals from which they came. Thus ore replacements of the mafites are computed as mafites, kaolin as feldspar, etc., chlorite as a biopyribole, analcite as feldspathoid, pseudoleucite as leucite, etc.

GLASS

Glass must be computed from an analysis. One can usually surmise its composition from the character of the phenocrysts and the appearance of the rock as a whole. When undetermined, the rock must be given a tentative name, such as hyaline-rhyolite, etc.

RULES FOR COMPUTING ROCKS FROM THEIR MODES

1. The sum of the minerals in the mode should be 100 ± 0.5. If less it should be recalculated to 100. The sum of the leucocrates (quarfeloids plus auxiliary minerals) determines the class.

Class 1. Leucocrates form more than 95 per cent of the total component.
Class 2. Leucocrates between 95 (inclusive) and 50 per cent.
Class 3. Leucocrates between 50 (inclusive) and 5 per cent.
Class 4. Leucocrates between 5 (inclusive) and 0 per cent.

2. Determine the orders in Classes 1, 2, and 3 directly from the Ab–An ratio in the plagioclase.

Order 1. $Ab_{100}An_0$ to $Ab_{95}An_5$.
Order 2. $Ab_{95}An_5$ (inclusive) to $Ab_{50}An_{50}$.
Order 3. $Ab_{50}An_{50}$ (inclusive) to Ab_5An_{95}.
Order 4. Ab_5An_{95} (inclusive) to Ab_0An_{100}.

In Class 4 the orders are determined by the percentage of "ores." Reduce the sum of biotite, olivine, pyribole, and "ores" (including cassiterite, chromite, etc.) to 100, dropping the minor mafites, apatite, garnet, perofskite, any small amount of quarfeloids, etc. The percentage of "ores" determines the order.

Order 1. 0 to 5 per cent "ores."
Order 2. 5 (inclusive) to 50 per cent "ores."
Order 3. 50 (inclusive) to 95 per cent "ores."
Order 4. 95 (inclusive) to 100 per cent "ores."

3. Determine the family. In Classes 1, 2, and 3, first recalculate the quarfeloids to 100. The amount of quartz (or feldspathoid) thus determined immediately locates a row of five horizontal pigeonholes, in one of which the rock belongs. Recalculate[1] Kf plus plagioclase to 100 and determine the proper point on the

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[1] It is immaterial whether the orthoclase-plagioclase ratio is taken from the original values or from those reduced as quarfeloids to 100. The results are naturally the same.

Kf-Plag base line. This determines the vertical series of pigeonholes, and its intersection with the horizontal series gives the proper position for the family. (If plotted graphically, the family is directly determined by the position of the intersection of three lines, as shown in Example 1, below.) Only when the point falls very close to a division line is it necessary to compute the position accurately. The separation points for Kf-Plag are at 0–5–35–65–95–100.

In Class 4, Orders 1, 2, and 3, recalculate the olivine, pyroxene, and biotite plus amphibole to 100 (Fig. 5) and find the proper position graphically, or find the position analytically by taking the ratio of the mineral of one corner to each of the others; thus amphibole to olivine, amphibole to pyroxene, and olivine to pyroxene. The division points are 0–5–50–95–100.

In Class 4, Order 4, the writer groups all the ores in a single family, but classifies the various hematite, ilmenite, magnetite, etc., ores as subfamilies. If desired, they may be further separated. If accessory dark minerals, not used in the computation, are abundant, they determine subfamilies and may be mentioned in the rock name.

4. Subfamilies. In all classes subfamilies are based on 0–5–50–95–100 division points, after the manner shown in Figure 1.

A FEW POINTS TO BE OBSERVED

Any percentage value falling exactly on a line should be moved toward the opposite apex of the triangle except as indicated below. Thus a syenite with 5 per cent quartz is classified with granite, a rock with 95 per cent mafites belongs to Class 4, and one with 95 per cent quarfeloids to Class 2; $Ab_{95}An_5$ belongs to Order 2, and Ab_5An_{95} to Order 4. If the divisions fall on the 50-50 line of quartz they are moved upward, or on the 50-50 line of foids downward, toward the apices; that is, they are placed in Families 1 to 5 or 26 to 30. Rocks falling on the 50-50 light-dark line are classed with the dark, while along the plagioclase line $Ab_{50}An_{50}$ is classed with basic plagioclase. Rocks falling on the line separating the two triangles, namely, on the feldspar base line, usually should be classed on the quartz side, that is, on the normal side, but if the rock has affinities with alkalic rocks it should be placed on the foid side.

In Class 4 the medial lines pass through the center of gravity of the triangle, consequently rocks falling on these lines are arbitrarily moved into the families shown by the small arrows in Figure 5.

For classificatory purposes, it is seldom necessary to make exact determinations of the mineral percentages. Unless the proportions are such that the rock falls near a division line, a simple inspection will answer. Thus it is usually possible to determine very quickly whether the dark constituents are less than 5 per cent, between 5 and 50 per cent, etc.; whether the quartz forms more or less than 5 per cent of the light constituents, and whether the orthoclase forms more than 95 per cent, between 95 and 65, between 65 and 35, between 35 and 5, or less than 5 per cent of the total feldspar. Of course, if the rocks are to be plotted as points in the triangle, more careful determinations are necessary.

EXAMPLES

Example 1.—A granodiorite having the composition

Quartz	18.0		= 23.1	
Orthoclase	18.0		= 23.1	= 30.0
Andesine ($Ab_{70}An_{30}$)	42.0		= 53.8	= 70.0
Total quarfeloids		78.0	100.0	100.0
Biotite	12.8			
Hornblende	9.0			
Magnetite	.1			
Titanite	.1			
Total mafites		22.0		
		100.0		

Percentage quarfeloids = 78. The rock belongs to Class 2.

$Ab_{70}An_{30}$ falls between 95 and 50. The order, therefore, is 2.

The family may be rapidly determined graphically. Plot 23.1 Qu, 23.1 Or, and 53.8 Ca*Na*f by drawing a horizontal line 23.1 above the base of the triangle, and an inclined line, parallel to the Qu-Plag line, 23.1 from that line. The intersection of the two in Family 9 determines the position of the rock. As a check, the point must also lie 53.8 from the Kf-Qu line.

To compute the family analytically: From the presence of 23.1 per cent quartz, the family must lie between numbers 6 and 10, since there is more than 5 per cent and less than 50 per cent quartz. Further, the ratio of Or to Ca*Na*f is 30 to 70, and since the orthoclase is between 5 and 35 per cent the family number is 9.

The rock number, therefore, is 229, that is, Class 2, Order 2, Family 9. (The number is to be read two two nine.)

Example 2.—A nephelite-monzonite with

Kf	21.5		= 39.0
Oligoclase ($Ab_{92}An_8$)	33.5		= 61.0
Total feldspar		55.0	100.0
Neph	27.5		
Sodal	8.5		
Total feldspathoids		36.0	
Total quarfeloids		91.0	
Aeg.-aug	5.0		
Biot	2.5		
Access	1.5		
		9.0	

Quarfeloid ratio 91, Class 2.

$Ab_{92}An_8$, Order 2.

Foids to feldspars = 36:55 = 39.5:60.5. Between Families 21 and 25.

Kf to Ca*Na*f = 39.0:61.0. Family 23.

Rock number is 2223. (To be read two two twenty-three.)

Example 3.—A lherzolite with

Augite	45.0	= 66.4
Hypersthene	20.0	
Olivine	30.0	= 30.6
Hornblende	3.0	= 3.0
Magnetite	2.0	100.0
	100.0	

Since there are neither feldspars, feldspathoids, nor quartz, the rock must belong to Class 4.

The ratio of ferromagnesian minerals to ores is 98:2; therefore the order is 1.

The ratio of pyroxene to olivine is 65:30=68:32; therefore the rock lies along the line of Families 6, 10, and 11. The ratio of pyroxene to hornblende is 65:3=96:4; therefore it belongs to Family 1, 4, 11, or 12. Family 11 is the only one common to both computations, consequently the rock number is 4111. (To be read four one eleven.)

The rock may be plotted by drawing one line parallel to the base and 30.6 above it, and another parallel to the amphibole-olivine line and 66.4 from it. The intersection of the two lines locates the rock. As a check, the third line, parallel to the remaining side of the triangle and at a distance of 3.0 from it, should cross the other two at their intersection.

NAMES PROPOSED FOR VARIOUS FAMILIES

On the basis of the foregoing subdivisions, nearly a thousand modal analyses have been plotted and names have been given to many of the families, most of them derived from plutonic rocks falling at the center points. In some cases, as in the quartz-rich types, family names were taken from differentiation rocks. In the tabulation (pp. 12–15) there are many blank pigeonholes, owing to lack of good modal descriptions. There are undoubtedly many rocks in most of the families here left blank, especially in Classes 2 and 3, but the majority of published rock descriptions lack mineral percentages, making them unavailable for classification. The writer is at present engaged in measuring the components of a great number of thin sections, most of them of classic rocks or of rocks which have been chemically analyzed.

Blank spaces in the tables below do not necessarily mean that rocks are wanting in these pigeonholes but may indicate that none falls near the center point, although, on the other hand, a solitary rare rock may, in some cases, give its name to the family, even though it is not at the center.

A certain system is used for the prefixes. The terms "granite," "syenite," "monzonite," "diorite," etc., are defined, and the addition of a prefix to any one indicates a definite modification. Where no specific name is available, "leuco-" is used to indicate rocks of Class 1, "meso-" those of Class 2, and "mela-" those of Class 3. In most cases the prefix "meso-" is unnecessary, since normal rocks belong to Class 2, and these are written without the prefix, the class being understood. Thus there are leuco-granites, granites, and mela-granites, respectively, in Classes 1, 2, and 3. Furthermore, syenites, monzonites, granodiorites, diorites, and even gabbros normally contain more than 5 and less than 50 per cent of dark constituents, whereby the prefix "meso-" is unnecessary.

Analogous rocks in the four orders of each class similarly have distinctive prefixes where no other names are available. The rocks of Order 1 have albite as their plagioclase; therefore an albite-monzonite is a monzonite whose plagioclase is albite, and in Order 4 an anorthite-monzonite is one containing orthoclase and anorthite. An albite-diorite means a rock all of whose plagioclase is albite; an albite-granite, on the other hand, means a granite containing some albite in addition to orthoclase, since granite itself is defined as a rock consisting of quartz, a biopyribole, orthoclase, and less plagioclase. That is to say, the term "granite" in itself conveys the idea of an orthoclase rock with some plagioclase, the latter indicated, except in normal rocks, by the prefix. The plagioclase in Order 2 is oligoclase to andesine, and that of Order 3 labradorite to bytownites. Acid and basic cannot be used as prefixes for these orders, since albite and anorthite, the end members of the acid and basic plagioclases, are set apart as Orders 1 and 2. Lime-soda and soda-lime are so much alike that one must always stop to think which is which. The prefixes "sodi-" and "calci-" are here suggested. As in the names of normal classes, here also normal rocks drop the prefix; "sodi-," therefore, is seldom necessary. To the rocks of the hinge families, namely those which contain no plagioclase, "ortho-" is prefixed; the feldspar present is orthoclase, microcline, microperthite, or anorthoclase.

TABLE I

CLASS 1. $\frac{\text{Quarfeloids}}{\text{Mafites}}$ between $\frac{100}{0}$ and $\frac{95}{5}$

Order 1 $Ab_{100}An_0$ to $Ab_{95}An_5$	Order 2 $Ab_{95}An_5$ to $Ab_{50}An_{50}$	Order 3 $Ab_{50}An_{50}$ to Ab_5An_{95}	Order 4 Ab_5An_{95} to Ab_0An_{100}
0 Silexite................	(=110)	(=110)	(=110)
1 Orthotarantulite	(=111)	(=111)	(=111)
2 Tarantulite	Granite-greisen		
3	Adamellite-greisen		
4	Granodiorite-greisen		
5	Tonalite-greisen		
6 Orthoalaskite	(=116)	(=116)	(=116)
7 Alaskite	Leucogranite		
8 Leuco-albite-adamellite	Leucoadamellite		
9 Leuco-albite-granodiorite	Leucogranodiorite	Leucogranogabbro	
10 Leuco-albite-tonalite	Leucotonalite	Quartz-anorthosite	
11 Orthosite	(=1111)	(=1111)	(=1111)
12 Leuco-albite-syenite	Leucosyenite		
13 Leuco-albite-monzonite	Leucomonozonite		
14 Leuco-albite-monzodiorite	Leucomonzodiorite	Leucomonzogabbro	Leuco-anorthite-monzogabbro
15 Albitite	Leucodiorite	Anorthosite	Anorthitite
16	(=1116)	(=1116)	(=1116)
17			
18			
19			
20	Dungannonite		
21	(=1121)	(=1121)	(=1121)
22			
23			
24 Leucolitchfieldite			
25 Leucomariupolite			
26	(=1126)	(=1126)	(=1126)
27			
28			
29			
30	Craigmontite		
31	(=1131)	(=1131)	(=1131)

TABLE II

CLASS 2. $\frac{\text{Quarfeloids}}{\text{Mafites}}$ between $\frac{95}{5}$ and $\frac{50}{50}$

Order 1 $Ab_{100}An_0$ to $Ab_{95}An_5$	Order 2 $Ab_{95}An_5$ to $Ab_{50}An_{50}$	Order 3 $Ab_{50}An_{50}$ to Ab_5An_{95}	Order 4 Ab_5An_{95} to Ab_0An_{100}
0 Meso-silexite	(=210)	(=210)	=(210)
1 Moyite	(=211)	(=211)	(=211)
2	Quartz-granite		
3	Quartz-adamellite		
4	Quartz-granodiorite		
5 Rockallite	Quartz-tonalite		
6 Orthogranite	(=216)	(=216)	(=216)
7 Albite-granite	Granite	Calcigranite	Anorthite-granite
8 Albite-adamellite	Adamellite	Calciadamellite	Anorthite-adamellite
9 Albite-granodiorite	Granodiorite	Granogabbro	Anorthite-granogabbro
10 Albite-tonalite	Tonalite	Quartz-gabbro	Quartz-anorthite-gabbro
11 Orthosyenite	(=2111)	(=2111)	(=2111)
12 Albite-syenite	Syenite	Calcisyenite	Anorthite-syenite
13 Albite-monzonite	Monzonite	Calcimonzonite	Anorthite-monzonite
14 Albite-monzodiorite	Monzodiorite	Monzogabbro	Anorthite-monzogabbro
15 Albite-diorite	Diorite	Gabbro, Norite	Anorthite-gabbro
16 Pulaskite	(=2116)	(=2116)	(=2116)
17	Nephelite-bearing syenite		
18	Nephelite-bearing monzonite		
19	Nephelite-bearing monzodiorite		
20	Nephelite-bearing diorite		
21 Ortho-nephelite-syenite	(=2121)	(=2121)	(=2121)
22 Albite-nephelite-syenite	Nephelite-syenite		
23 Albite-nephelite-monzonite	Nephelite-monzonite	Kulaite	
24 Litchfieldite	Nephelite-monzodiorite	Nephelite-monzogabbro	
25 Mariupolite	Nephelite-diorite	Nephelite-gabbro	
26 Naujaite	(=2126)	(=2126)	(=2126)
27 Beloeilite		Heronite	
28			
29			
30 Toryhillite		Lugarite	
31 Urtite, Fergusite, Uncompahgrite	(=2131)	(=2131)	(=2131)

TABLE III

CLASS 3. $\frac{\text{Quarfeloids}}{\text{Mafites}}$ between $\frac{50}{50}$ and $\frac{5}{95}$

Order 1 $Ab_{100}An_0$ to $Ab_{95}An_5$	Order 2 $Ab_{95}An_5$ to $Ab_{50}An_{50}$	Order 3 $Ab_{50}An_{50}$ to Ab_5An_{95}	Order 4 Ab_5An_{95} to Ab_0An_{100}
0	(=310)	(=310)	(=310)
1	(=311)	(=311)	(=311)
2			
3			
4			
5			
6 Mela-orthogranite	(=316)	(=316)	(=316)
7 Mela-albite-granite	Melagranite	Mela-calcigranite	
8 Mela-albite-adamellite	Mela-adamellite		
9 Mela-albite-granodiorite	Melagranodiorite	Melagranogabbro	
10 Mela-albite-tonalite	Melatonalite	Mela-quartz-gabbro	
11 Mela-orthosyenite	(=3111)	(=3111)	(=3111)
12 Mela-albite-syenite	Melasyenite		
13 Mela-albite-monzonite	Melamonzonite		
14 Mela-albite-monzodiorite	Melamonzodiorite	Melamonzogabbro	Ricolettaite
15 Mela-albite-diorite	Meladiorite	Melagabbro	Yamaskite
16 Orthoshonkinite	(=3116)	(=3116)	(=3116)
17 Shonkinite	Oligoclase-(andesine-) shonkinite	Labradorite-(bytownite-)shonkinite	
18			
19			
20			
21 Nephelite-shonkinite	(=3121)	(=3121)	(=3121)
22			
23			
24 Melalitchfieldite		Mela-nephelite-monzogabbro	
25 Melamariupolite		Theralite	
26	(=3126)	(=3126)	(=3126)
27			
28			
29			
30			
31 Bekinkinite, Missourite, Farrisite	(=3131)	(=3131)	(=3131)

TABLE IV

CLASS 4. $\frac{\text{Quarfeloids}}{\text{Mafites}}$ between $\frac{5}{95}$ and $\frac{0}{100}$

Order 1 "Ores" less than 5 Per Cent	Order 2 "Ores" between 5 and 50 Per Cent	Order 3 "Ores" between 50 and 95 Per Cent	Order 4 "Ores" more than 95 Per Cent
1 Dunite	Chromite-dunite Magnetite-dunite	Olivine-chromitite Olivine-magnetite	Chromitite Magnetite
2 Mica-peridotite, amphibole-peridotite, hornblende-picrite, cortlandtite.			
3 Valbellite, hornblende-diallage-peridotite, etc.			
4 Lherzolite, diallage-peridotite, wehrlite, harzburgite, saxonite.			
5 Included with Family 2 at present.			
6 Included with Family 3 at present.			
7 Cromaltite, hornblende-hypersthenite, etc.			
8 Amphibolites, hornblendites.			
9 Included with Family 7 at present.			
10 Included with Family 3 at present.			
11 Included with Family 4 at present.			
12 Diallagite, hypersthenite, websterite, ilmenite-enstatitite, etc.			

CLASS 1, ORDER 1

(110) Silexite MILLER. The term silexite was proposed by Miller[1] for pure igneous quartz rocks. Such rocks, frequently described under the names igneous quartz, quartz dikes, quartz veins, etc., represent the end members of pegmatitic intrusions. Greisen, an old Saxon miner's term, cannot be used for the family name, since it should properly be restricted to tin-bearing leucogranites. Furthermore, according to some authors, it is an altered rock, feldspar having been changed to quartz. Beresite ROSE[2] likewise cannot be used; it was shown by Helmhacker[3] to be an altered quartz-porphyry.

Besides pure quartz there are a number of other rocks falling in this family, namely such as are free from feldspars and mafites, and consist only of quartz and an auxiliary mineral, such as mica, tourmaline, topaz, etc. Among these are:

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[1] William J. Miller, "Silexite, a New Rock Name," *Science*, XLIX (1919), 149; also "Pegmatite, Silexite, and Aplite of Northern New York," *Jour. Geol.*, XXVII (1919), 28–54, in particular p. 30.

[2] Gustav Rose, *Mineralogisch-geognostische Reise nach dem Ural, dem Altai und dem Kaspischen Meere* (Berlin, 1837), I, 186.

[3] R. Helmhacker, "Der Goldbergbau der Umgebung von Berëzovsk am östlichen Abhange des Urals," *Berg- und Hüttenmännische Zeitung*, LI (1892), 83–84.

Esmeraldite SPURR. The terms greisen and beresite have been used more or less loosely for quartz-muscovite rocks, although, as mentioned above, they have other meanings. Spurr[1] definitely applied the term esmeraldite to rocks from the southern Klondike district, Esmeralda County, Nevada, which consist only of quartz and muscovite.

Syn.: Greisen (in part), Glimmer-greisen JOKÉLY.[2]

Tourmalite.[3] This term is here suggested for rocks consisting only of tourmaline and quartz, to which the name hydrotourmalite was given by Daubrée.[4] Other synonyms are Schörlquarzit, Schörlfels, Schörlschiefer, Turmalinschiefer, Turmalinfels, schorl-rock, Carvoeira,[5] etc.

Topazite. Topazite is here suggested for rocks containing only quartz and topaz.

Syn.: Topasfels WERNER,[6] Topazogène CHARPENTIER,[7] topaz-rock.

(111) **Orthotarantulite.** The prefix "ortho-" is used here and in all of the hinge families to indicate feldspathic rocks which contain less than 5 per cent plagioclase. They include, therefore, orthoclase, microcline, microperthite, and anorthoclase rocks. See note under (112). Thus defined, orthotarantulite is a tarantulite with less than 5 per cent of its feldspar plagioclase.

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[1] J. E. Spurr, "The Southern Klondike District, Esmeralda County, Nevada," *Econ. Geol.*, I (1906), 382.

[2] Johann Jokély, "Das Erzgebirge im Leitmeritzer Kreise in Böhmen," *Jahrb. d. k. k. geol. Reichsanst.*, IX (1858), 566.

[3] In the following pages proposed new names are in bold-face type. Where the prefix indicates a newly formed group it is shown thus, **ortho**granite.

[4] M. Daubrée, "Sur le gisement, la constitution et l'origine des amas de minerai d'étain," *Ann. d. Mines*, XX (1841), 84.

[5] W. L. v. Eschwege, *Beiträge z. Gebirgskunde Brasiliens* (1832), p. 178.

[6] A. G. Werner, *Kurze Klassification und Beschreibung der verschiedener Gebirgsarten* (Dresden, 1787), p. 15.

[7] J. de Charpentier, *Vom Schneckenstein, oder dem sächsischen Topasfelsen* (Prag, 1776).

Syn.: Alaskite-quartz Spurr (in part),[1] Feldspar-greisen Jokély (in part).

(112) **Tarantulite.** Spurr[2] used the term alaskite-quartz for a transition rock between alaskite and igneous quartz which occurs in the Missouri mine, near Tarantula Spring, Nevada. As a simpler term the name tarantulite is here proposed for Family 2, which contains orthoclase and less albite.

Syn.: Alaskite-quartz Spurr (in part), Feldspar-greisen Jokély (in part).

(116) **Ortho**alaskite. The term alaskite was given by Spurr[3] to leucocratic rocks which contain alkali feldspars (orthoclase, microcline, microperthite), with or without albite. Here they are divided into two groups. Those without albite are included under the name orthoalaskite (see note under (111)), while those with albite are normal alaskites of Family 7 (117).

Runite Pinkerton.[4] Syn.: Pegmatite Haüy,[5] Schriftgranit, Hebräischerstein, graphic-granite, etc.

Orthotordrillite. The extrusive equivalent of orthoalaskite is orthotordrillite. The name tordrillite was given by Spurr[6] to the extrusive equivalent of alaskite. In the present classification only the tordrillites with no plagioclase are included in this family.

(117) Alaskite Spurr. See under orthoalaskite (116).

Tordrillite Spurr. See under orthotordrillite (116) above.

Syn.: Rhyalaskite.[7]

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[1] J. E. Spurr, "Ore Deposits of the Silver Peak Quadrangle, Nevada," *U.S. Geol. Surv., Prof. Paper 55* (1906), p. 61.

[2] *Ibid.*

[3] J. E. Spurr, "Classification of Igneous Rocks According to Composition," *Amer. Geol.*, XXV (1900), 229–30.

[4] J. Pinkerton, *Petrology* (London, 1811), II, 85.

[5] Ascribed to Haüy by Brongniart, "Essai d'une classification minéralogique des roches mélangées," *Jour. d. Mines*, XXXIV (1813), 32.

[6] J. E. Spurr, "Classification of Igneous Rocks According to Composition," *Amer. Geol.*, XXV (1900), 230; also "Reconnaissance in Southwestern Alaska in 1898," *U.S. Geol. Surv., Ann. Rept.*, XX, Part VII (1900), p. 189.

[7] J. H. Farrell, *Field Geology* (New York, 1912), p. 160, Table II.

(118) **Leuco-albite**-adamellite. No confusion can result here from the use of the word albite as a prefix (see p. 48, above). It cannot be thought to mean that the albite replaces (proxies) the potash feldspar, since the term adamellite conveys the quartz-monzonitic idea, but it clearly shows that the plagioclase present is albite. For the use of the term adamellite for quartz-monzonite see note under (228).

Leuco-albite-dellenite. The extrusive equivalent of the preceding.

(119) **Leuco-albite**-granodiorite. See note under (118).

(1110) **Leuco-albite**-tonalite. See note under (118). For the use of tonalite for quartz-diorite see (2210).

(1111) Orthosite TURNER. These rocks are leuco-potash-syenites or leuco-orthosyenites. For those composed entirely of orthoclase, Turner[1] proposed the term orthosite. Pure anorthoclase or sanidine rocks belong here also. The former might properly be called anorthosites. This term, however, is now so firmly attached to plagioclase rocks without mafites that no change is possible. See note under anorthosite (1315).

Sanidinite TSCHERMAK.[2]
Microclinite LOEWINSON-LESSING.[3]
Anorthoclasite LOEWINSON-LESSING.[4]

(1112) **Leuco-albite**-syenite. A temporary term for leucocratic syenites, consisting essentially of orthoclase with some albite. See note under (217).

(1115) Albitite TURNER. Turner's[5] term for rocks which consist essentially of albite.

(1124) **Leuco**litchfieldite. See note under (2124). This term is preferable to the longer term leuco-albite-nephelite-monzodiorite.

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[1] H. W. Turner, "The Nomenclature of Feldspathic Granolites," *Jour. Geol.*, VIII (1900), 106-10.

[2] Gustav Tschermak, "Verhandlungen der k. k. geol. Reichs. Sitzung am 6 März, 1866," *Jahrb. d. k. k. geol. Reichsanst.*, XVI (1866), 34.

[3] F. Loewinson-Lessing, "Kritische Beiträge zur Systematik der Eruptivgesteine," *Tscherm. Min. Petr. Mitth.*, XX (1901), 114.

[4] *Loc. cit.*

[5] H. W. Turner, "The Nomenclature of Feldspathic Granolites," *Jour. Geol.*, VIII (1900), 111.

(1125) **Leuco**mariupolite. See note under (2125). It is a leuco-albite-nephelite-diorite.

(1131) Here belong rocks consisting of one or more feldspathoids, without feldspars or dark constituents. The type rock is pure nephelite. For the corresponding extrusives Loewinson-Lessing[1] proposed noseanite, nephelinolith, and amphigenite. Noseanite, however, was previously used by Bořický[2] for an amphibole-(plus 50 per cent) nephelite-(20–40 per cent) noselite rock with small amounts of magnetite and olivine, while amphigenite was used by Cordier[3] for rocks now called leucite-tephrites.

Sodalitsten STEENSTRUP[4] probably belongs to this family.

CLASS 1, ORDER 2

(120) These rocks are included under Order 1, since the variations produced by small amounts of different plagioclases are unessential.

(121) Included under Order 1.

(122) Granite-greisen JOKÉLY. Syn.: Feldspathgreisen JOKÉLY. Jokély[5] applied the term Granit- or Feldspathgreisen to rocks consisting essentially of quartz and feldspar with some muscovite. The feldspar was determined megascopically only and was spoken of as "allem Anschein nach durchgänglich Orthoklas." If ordinary granites are divided into orthogranites and normal granites, so also should the granite-greisens be divided, and there would be orthogranite-greisens (121) and granite-greisens (122). But (121) is the hinge family and is the same as (111); consequently the former name need not be considered, and the term granite-greisen can be applied to the quartz-feldspar rock of Family 2. The presence or absence of muscovite will not change the classification,

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[1] F. Loewinson-Lessing, "Kritische Beiträge zur Systematik der Eruptivgesteine, IV," *Tscherm. Min. Petr. Mitth.*, XX (1901), 114.

[2] Emanuel Bořický, "Petrographische Studien an den Basaltgesteinen Böhmens," *Arch. f. d. naturw. Landesdurchf. v. Böhmen*, Band II, Abt. ii, Th. ii, pp. 41, 78–79.

[3] Cordier and d'Orbigny, *Description des roches* (Paris, 1868), pp. 114–15.

[4] N. V. Ussing, "Mineralogisk-petrografiske Undersögelser af Grönlandske Nefelinsyeniter og beslaegtede Bjaergarten, 1894," *Meddel. om Grönl.*, XIV (1898), 128.

[5] Johann Jokély, "Das Erzgebirge im Leitmeritzer Kreise in Böhmen," *Jahrb. d. k. k. geol. Reichsanst.*, IX (1858), 567.

though when it is present the rock may be classed as a subfamily, comparable to one in the normal granite family, namely as Muscovite-granite-greisen.

(123) **Adamellite-greisen.** The rock for which the term adamellite-greisen is here proposed is related to the quartz-monzonites (adamellites) as granite-greisen is to normal granite. For the use of the term adamellite for quartz-monzonite see note under (228).

(124) **Granodiorite-greisen.** See note under (123).

(125) **Tonalite-greisen.** See note under (123).

(127) **Leuco**granite differs from normal granite (227) in the practical absence of mafic minerals. It therefore consists of quartz, orthoclase, and a less amount of oligoclase or andesine.

Leucorhyolite. The extrusive equivalent of the preceding.

(128) **Leuco**adamellite. See note under (127).

Leucodellenite. The extrusive equivalent of the preceding.

(129) **Leuco**granodiorite. See note under (127).

Leucorhyodacite. The extrusive equivalent of preceding. See note under rhyodacite (229).

(1210) **Leuco**tonalite. See note under (127) for the relationship between this rock and normal tonalite. For the use of tonalite for quartz-diorite see (2210). According to the kind of feldspar present, the leucotonalites are divided into quartz-oligosites Turner (quartz-oligoclasites), and quartz-andesinites Turner. See note under (1215).

Quartz-oligosite Turner.

Quartz-andesinite Turner.

Leucodacite. The extrusive equivalent of leucotonalite.

(1212) **Leuco**syenite. See note under (127).

Leucotrachyte. The extrusive equivalent of preceding.

(1213) **Leuco**monzonite. See note under (127).

Leucolatite. The extrusive equivalent of preceding.

(1214) **Leucomonzodiorite.** In the former paper the writer[1] suggested the term syenodiorite, from analogy with granodiorite, for quartz-free plagioclase rocks with some orthoclase. Under (229) he shows the objection to the term granodiorite, an objection which also applies to the word syenodiorite. The latter term, consequently, is here withdrawn, and monzodiorite is substituted as better indicative of a rock intermediate between monzonite and diorite. Leucomonzodiorite is the name of the corresponding rock in Class 1.

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[1] Albert Johannsen, "Suggestions for a Quantitative Mineralogical Classification of Igneous Rocks," *Jour. Geol.*, XXV (1917), 89.

Leucoandelatite. See note under (2214). The extrusive equivalent of preceding. Leucotrachyandesite would be the extrusive name by analogy with granodiorite, but trachyandesite has been used in the sense of latite as well as for an intermediate rock of the foyaite series[1] and comparable to trachydolerite of the gabbro series.

(1215) **Leuco**diorite. According to the kind of plagioclase present, the leucodiorites are divided into oligosites TURNER[2] (oligoclasites) and andesinites TURNER.[3]

Oligosite TURNER.

Andesinite TURNER.

Leucoandesite. The extrusive equivalent of leucodiorite.

(1220) Dungannonite ADAMS and BARLOW. A leucocratic nephelite-bearing diorite with considerable corundum (13.24 per cent) from Dungannon, Ontario, was described and named dungannonite by Adams and Barlow.[4] It is not typical of the family on account of the presence of corundum, but the name is here used since this rock is the only representative of the family yet located in the literature.

(1230) Craigmontite ADAMS and BARLOW. The name craigmontite was given by Adams and Barlow[5] to a nephelite-oligoclase-muscovite rock from Craigmont, Ontario. While the mode given in the report of the Canadian Geological Survey is calculated from the analysis, the actual mineral composition is probably also represented by it. The craigmontite type contains muscovite, but the name may be applied, with a proper prefix, to any oligoclase-nephelite rock of Family 30, for example aegirite-craigmontite, etc.

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[1] H. Rosenbusch, *Mikroskopische Physiographie der massigen Gesteine* (4th ed.; Stuttgart, 1908), p. 1036.

[2] H. W. Turner, "The Nomenclature of Feldspathic Granolites," *Jour. Geol.*, VIII (1900), 111.

[3] *Ibid.*

[4] Frank D. Adams and Alfred E. Barlow, "Geology of the Haliburton and Bancroft Areas, Province of Ontario," *Geol. Surv. Canada, Mem. 6* (Ottawa, 1910), p. 322.

[5] *Ibid.*, p. 313.

CLASS 1, ORDER 3

(139) **Leucogranogabbro.** While adam-gabbro would be more correct than granogabbro for the rocks of this family, the term is objectionable in sound, and, furthermore, since granodiorite is so firmly established that it must be retained, granogabbro as an analogous term should also be retained. See note under granodiorite (229).

Leucorhyobasalt. For the same reason that rhyodacite is retained rhyobasalt is used. See note under (229). Strictly speaking the term should be leuco-rhyo-quartz-basalt, but the prefix "rhyo-" may be considered as indicative of the presence of quartz.

(1310) Quartz-anorthosite. See note under (1315).

Leuco-quartz-basalt. The extrusive of the above.

(1314) **Leucomonzogabbro.** The objection to syenodiorite, mentioned under (1214), applies also to syenogabbro, which was previously proposed by the writer.[1] That term is now withdrawn and monzogabbro is substituted. See note under (2314).

(1315) Anorthosite HUNT. The term anorthosite was proposed by T. Sterry Hunt[2] for rocks composed chiefly of plagioclase (labradorite in most Canadian occurrences). The name is derived[3] from *anorthose*, originally used by Delesse for triclinic feldspars, although now used for anorthoclase. Anorthosite, consequently, properly should not be applied to plagioclase rocks. It is in such general use, however, that it must either be dropped entirely or else used in the sense of Hunt. Turner[4] would apply the term to anorthoclase rocks without mafic minerals, and would divide the basic plagioclase rocks, now called anorthosites, into labradites and anorthitites, according to the kind of plagioclase present, presumably dividing the bytownite rocks between them. Since most anorthosites are labradorite rocks, the term may well be confined to the labradorite-bytownite rocks of Class 1, Order 3, leaving the anorthite rock, anorthitite, in a class by itself (1415).

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[1] Albert Johannsen, "Suggestions for a Quantitative Mineralogical Classification of Igneous Rocks," *Jour. Geol.*, XXV (1917), 89.

[2] T. Sterry Hunt, *Geology of Canada* (Montreal, 1863), p. 22.

[3] Frank D. Adams, "Über das Norian oder Ober-Laurentian von Canada," *Neues Jahrb., B.B.*, VIII (1893), 423.

[4] H. W. Turner, "The Nomenclature of Feldspathic Granolites," *Jour. Geol.*, VIII (1900), 106–11.

Labradite TURNER.

Bytownitite.

Leucobasalt. The extrusive equivalent of anorthosite.

CLASS 1, ORDER 4

(1414) **Leuco-anorthite-monzogabbro.** A simpler name should be used here when a rock near the center point is described.

(1415) Anorthitite TURNER.[1] See note under (1315).

[1] *Ibid.*

[*To be continued*]